

WSDOT's Unstable Slope Management Program

for the Highway Construction Program has decreased from approximately \$1400 million in 2001-2003 to \$650 million in 2009-2011. This reduction in non-dedicated State and Federal funds has made it essential for WSDOT to evaluate the performance of its highway system and determine how that performance will change as a result of different investment alternatives in the future.

In 2004, the department evaluated how the highway system was performing and developed a 10-year Asset Management Plan to identify investment levels necessary for building the 2005-2007 Highway Preservation Program. At that time, the department estimated that it would take an additional \$100 million over the next 10 years to retrofit the currently identified high- and moderate-risk slopes. That evaluation recognized that emergency slope failures would probably continue, and set aside funding for this purpose in addition to the \$100 million for the planned retrofit work.

Figure 3: Unstable Slopes Projects - Actual Expenditures
Emergency Relief vs. Programmed Project
Dollars in Thousands

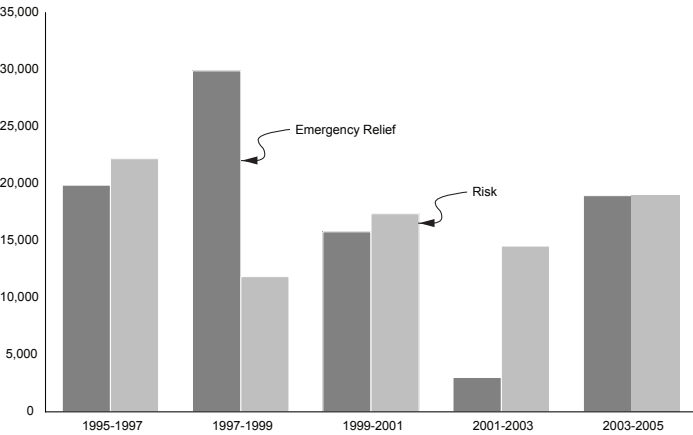


Figure 3 shows the dollars spent on programmed and emergency unstable slopes projects from 1995 to 2005.

Source: WSDOT System Analysis and Program Development

Solutions to Meet the Current Need to Reduce Public Risk

The present funding proposal is for \$21 million per biennium (projected to 2015) for planned work in the unstable slope management program. A higher level of funding commitment would allow for more unstable slopes to be mitigated, and therefore reduce public risk. In preparing for the 2007-09 budget development process, the department will review its current Asset Management Plan for unstable slope needs, adjust it for the accomplishments of the past two years, add any new needs, and evaluate the benefits of accelerating the rate at which unstable slope risks are addressed.



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The Problem

The Washington State Department of Transportation manages 7,048 miles of highway facilities that traverse widely varying terrains with complex geologic landforms. Unstable slopes, including landslides, rock falls, and debris flows of all sizes can impact highways when they fail. Failure of unstable slopes poses a potential risk to the traveling public and adversely affects regional commerce when resulting highway closures occur.

For More Information

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Processes Leading to Slope Instability

Slope instability is a category of natural hazard that refers to the movement of a soil or rock mass under the influence of gravity. Rock falls occur on both natural and excavated slopes. Causes of rock falls include a combination of natural processes and man-made influences, acting singly or in combination, to dislodge discrete blocks of rock. Usually planes of weakness termed “discontinuities” physically divide the rock mass into an assemblage of blocks.

Landslides are a category of natural hazards that involve the downslope movement of soil materials under the influence of gravity. Soil slope failures generally fall into two categories: 1) deep seated rotational failures or translational slides and 2) shallower debris flows and slides. Generally, rotational-type slope failures occur more slowly than debris flows and slides, which can occur quite rapidly. Landslide mechanisms involve either an increase in driving forces or a reduction of resisting forces (i.e. loss of shear strength of the soil).

Distinction between Hazard and Risk

It is important to understand the terms “hazard” and “risk”. Rock fall or soil slope failures are geologic processes categorized as natural hazards. These natural processes include landslides, debris avalanches, slope creep movement, soil piping, snow avalanches and so on. These events occur in nature and have done so since the geologic evolution of landforms began. In some cases, the activities of humans can influence the occurrence of natural hazard events. A reference to a high hazard means that there is a high likelihood an event will occur.

Risk refers to the consequences of a natural hazard event if it occurs. It is easy to envision an event that has absolutely no consequence in terms of human activity, for example a snow avalanche in the remote mountains. The same natural hazard perched above a ski resort would represent a significant risk.

The hazards that most interest engineers in are those that have both a high likelihood of occurrence and a high likelihood of causing damage, injuries, death or severe economic impacts. Applied to highway slopes, it is necessary to assess both the degree of hazard in terms of the rock or soil becoming dislodged from the slope and the potential damage (risk) it could inflict based on its energy, probable trajectory and the likelihood of something vulnerable being in its path.

How we manage Unstable Slopes

Prior to 1995, unstable slopes were stabilized reactively after they had failed. To address unstable slope issues with a proactive approach, a budget category in the Highway Preservation Program for Unstable Slopes was established in 1995. The target investment level for this category in the highway system need was estimated at approximately \$300 million over 10 biennia. WSDOT developed the Unstable Slope Management System (USMS) to provide a methodology to rationally evaluate known unstable slopes within the WSDOT highway system. The method focuses on balancing hazard and risk in prioritizing slopes for the allocation of funds for proactive stabilization efforts.

WSDOT regional offices performed the initial unstable slopes identification process. This resulted in a baseline inventory of over 2500 sites. These known slopes are scored using a numerical rating system based on eleven criteria that identify the hazard and measure the potential risk factors to the highway facility if a slope fails. Based on the numerical rating system, a site may have a score ranging from 33 (lowest) to 891 (highest), the higher number representing the greater risk to the highway facility at that location. Table 1 identifies the rating factors. Since the inception of the USMS, the number of slopes in the inventory has increased to about 2700. Detailed numerical ratings have been completed for almost all known unstable slopes statewide. Figure 1 identifies unstable slopes along state routes in Washington State.

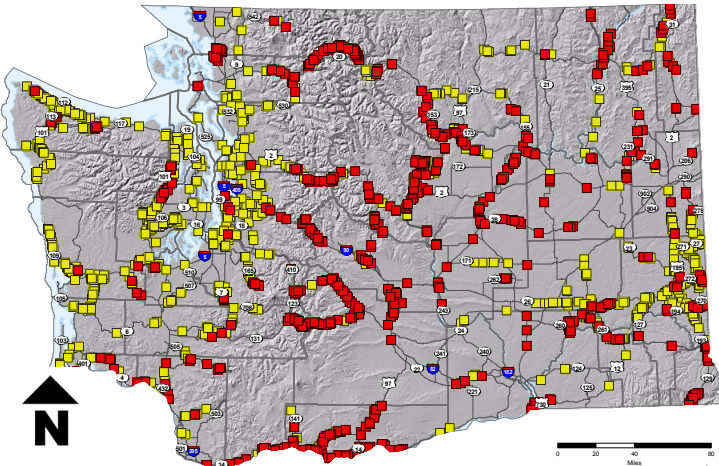


Figure 1
Unstable Slopes along State Routes in Washington State

Rockfall Landslide/Debris Flows

Source: Unstable Slope Management System (USMS)
Date: 11/23/2005

The next part of the process is when geotechnical specialists with expertise in slope stability provide a description of the slope stability problem, and develop conceptual slope mitigation designs and cost estimates. A simple benefit-cost analysis compares the cost of a 24-hour traffic delay and the maintenance costs over twenty years to what it would cost to

Rating Criteria

Category	Points = 3	Points = 9	Points = 27	Points = 81
Problem type: soil	Cut or fill slope erosion	Settlement or piping	Slow moving landslides	Rapid landslides or debris flows
Problem type: rock	Minor rockfall Good catchment	Moderate rockfall Fair catchment	Major rockfall Limited catchment	Major rockfall No catchment
Average daily traffic	<5,000	5,000 To 20,000	20,000 To 40,000	>40,000
Decision site distance	Adequate site distance	Moderate site distance	Limited site distance	Very limited site distance
Impact of failure on roadway	<50 Feet	50 To 200 feet	200 To 500 feet	>500 Feet
Roadway impedance	Shoulder only	1/2 Roadway	3/4 Roadway	Full roadway
Average vehicle risk	<25% Of the time	25% To 50% of the time	50% To 75% of the time	>75 % Of the time
Pavement damage	Minor - not noticeable	Moderate - driver must slow	Severe - driver must stop	Extreme - not traversible
Failure frequency	No failures in last 5 years	One failure in last 5 years	One failure each year	More than one failure per year
Annual maintenance costs	< \$5000 per year	\$5000 to \$10000 per year	\$10000 to \$50000 per year	>\$50000 per year
Economic factor	No detours required	Short detours < 3 miles	Long detours > 3 miles	Sole access no detours
Accidents in last 10 years	0 To1	2 To 3	4 To 5	>5

mitigate the slope hazard. Based on this approximate benefit-cost comparison, sites with a ratio of 1 or greater are placed on a prioritized list of slopes to be programmed for remediation. Currently, WSDOT prioritizes and programs remediation for unstable slopes that have a numerical rating of 350 or greater along interstate highways, principal arterials, and other highway facilities with traffic volumes of 5000 vehicles a day or greater, and a benefit-cost ratio of 1.0 or greater. Conceptual designs and cost estimates have been completed on 433 unstable slopes as part of the ongoing prioritization process. Figure 2 identifies mitigated slopes along state routes in Washington State.

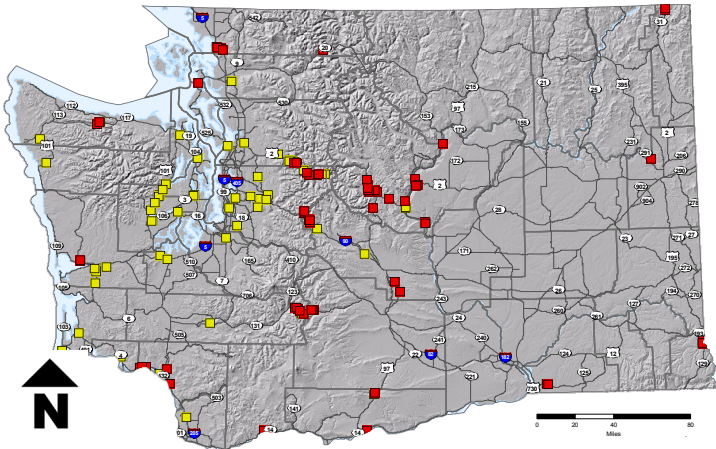


Figure 2
Mitigated Slopes along State Routes in Washington State

Mitigated Rockfall Mitigated Landslide/Debris Flows

Source: Unstable Slope Management System (USMS)
Date: 11/23/2005

WSDOT’s Unstable Slope management program is a proactive, infrastructure- preservation program that seeks to cost-effectively reduce the risk of moderate- to high-hazard unstable slopes from

adversely impacting our highest priority state highway facilities. The mitigation objective is to achieve long-term risk reduction. Therefore, the mitigation must either be a permanent solution or provide a reasonable performance life (>20 years).

Under the existing USMS procedures, a slope that qualifies for stabilization receives a comprehensive (i.e., 20-year design life) treatment. In other words, stabilization is all or nothing at a given site. In some cases, a minimal amount of slope treatment can remediate a large component of the risk at a given site, for example, hand scaling of a rock slope. WSDOT is exploring a new methodology to implement a risk reduction strategy that compliments the current slope stabilization program. One approach is to allocate \$1 million in funds for risk reduction that would be available each biennium. This would be in addition to the \$20 million earmarked for programmed sites on the comprehensive slopes stabilization program. On an annual basis, WSDOT Geotechnical Division and regional personnel would jointly determine the sites to include in this risk reduction strategy.

Managing Risk

Between 1995 and 2005, WSDOT spent approximately \$103 million on stabilizing more than 75 programmed unstable slopes. In addition, the department spent another \$97 million on unforeseen emergency slope corrections, for a total investment in unstable slopes of \$200 million over 5 biennia.

The department’s funding of non-dedicated dollars

